Types of Biosensors

Based on the type of transducer:

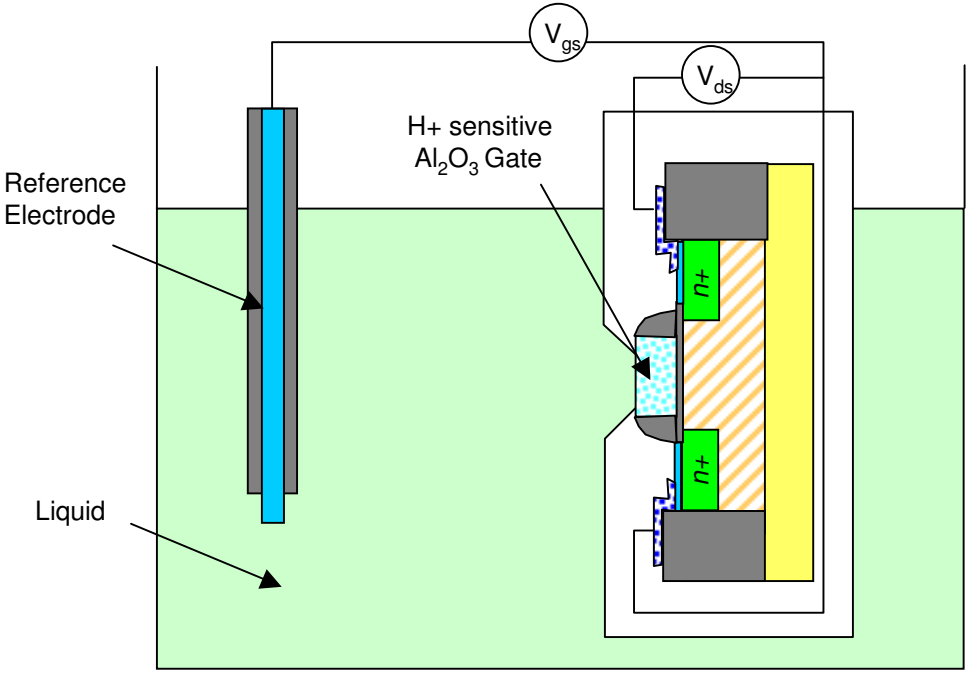
1. **Piezoelectric Biosensor**
   - Transducer is a vibrating crystal.
   - The transducer vibrates when there is change in mass.

2. **Optical Biosensor**
   - Based on Emission, absorption or scattering of light.
   - Don't require electrical contacts.

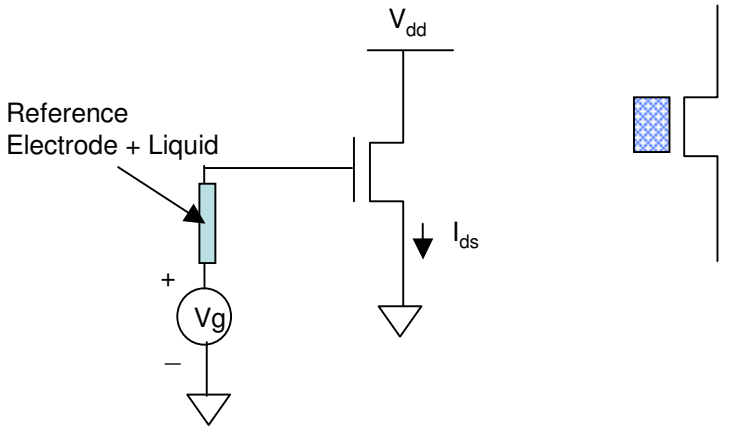
3. **Electrochemical Biosensor**
   - Operate at constant temperature conditions.
   - An electric field is applied between two electrodes.

   a. **Conductometric Biosensor -** measures electrical conductivity.
   b. **Amperometric Biosensor** - measures electrical current.
   c. **Ion sensitive Biosensor** - measures the charge density variations.

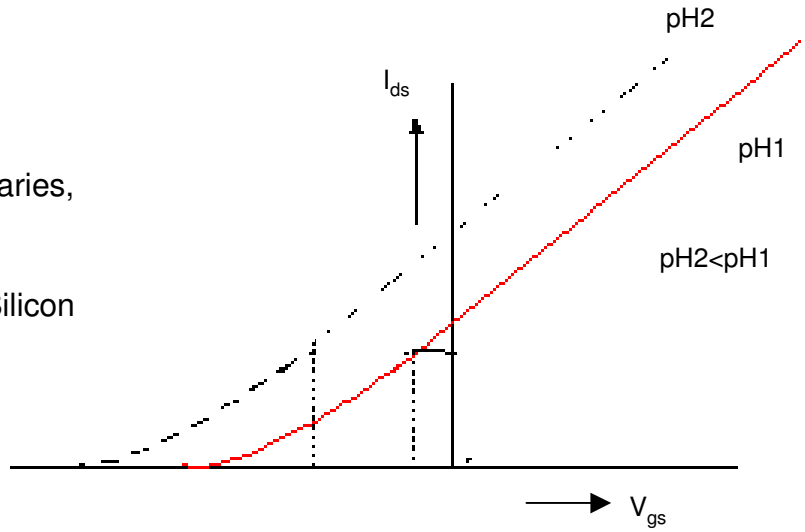
ISFET (Ion Sensitive FET)



Symbol for ISFET



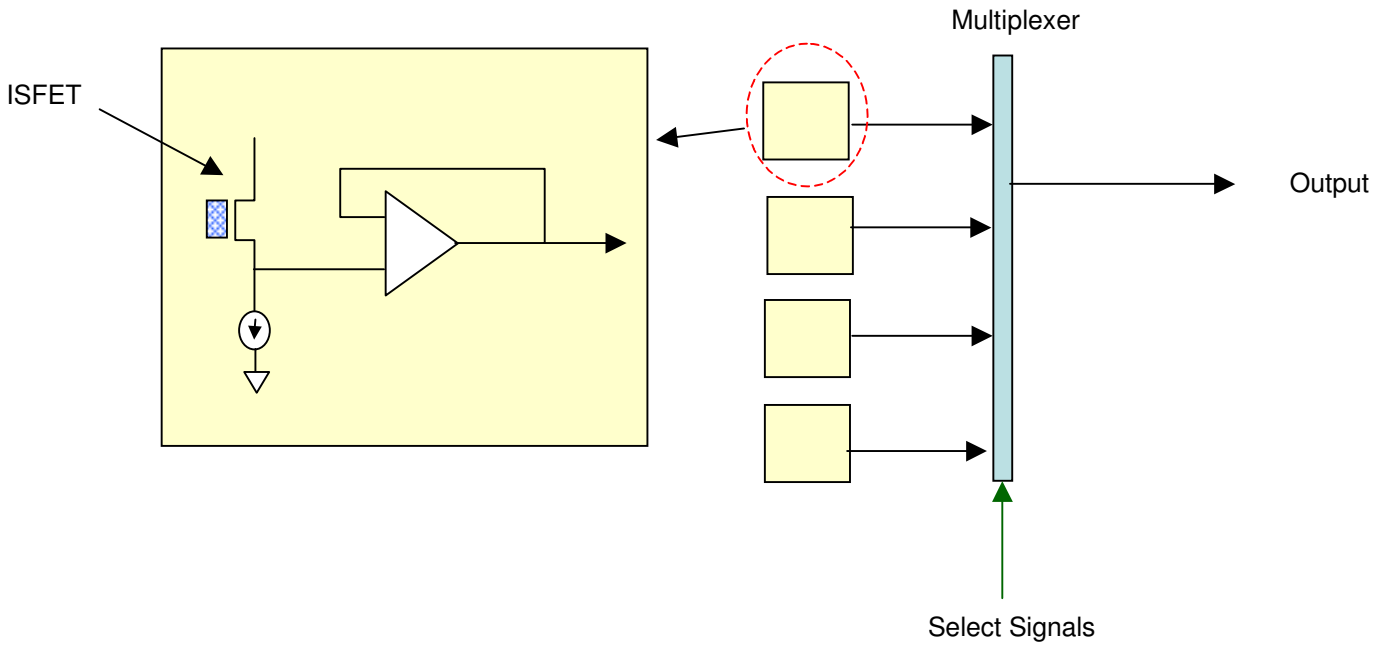
- Applied voltage to the gate is varied when the pH of the liquid varies, which in turn changes I_{ds}
- Here Al_203 is used which is sensitive to H+
- Other possible ion selective membranes are Tantulam Oxide, Silicon Nitride etc
- Reference Electrode. Eg. Ag/AgCl, saturated colomel



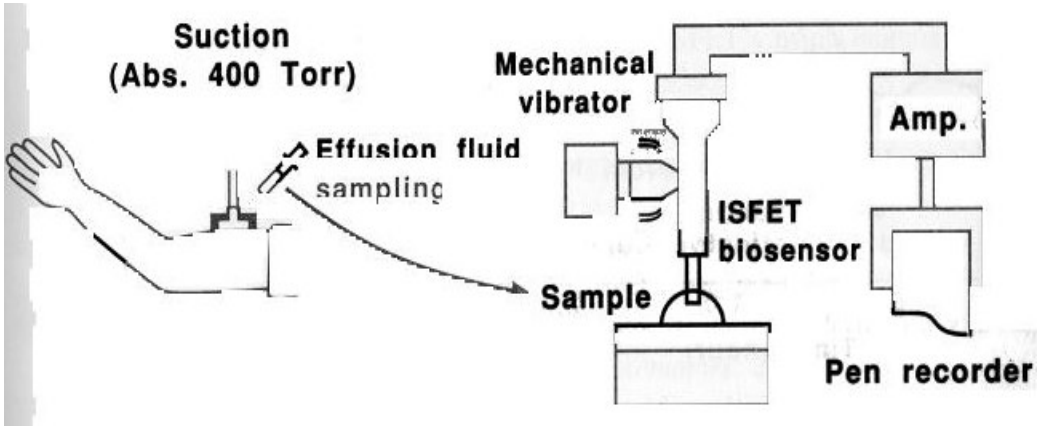
Enzymatic Reactions used for FET Sensors

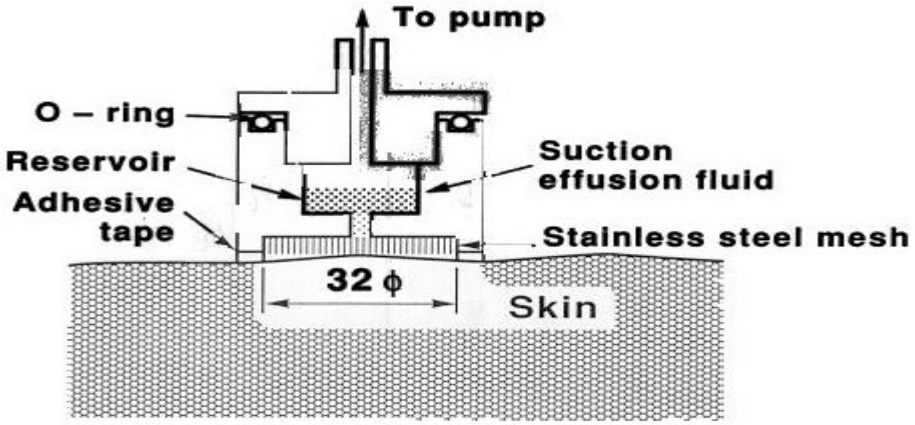
Substrate	Enzyme	Reaction
Pencillin	Pencillinase	Pencillin $\xrightarrow{\text{Hydrolysis}}$ Pencilloic acid
Urea	Urease	Urea + H^+ $\xrightarrow{\text{Hydrolysis}}$ $2NH_4^+ + HCO_3^-$
Glucose	Glucose oxidase	Glucose+0_2 $\xrightarrow{\text{Oxidation}}$ Gluconolactone+H_2O_2
	Gluconolactonase	Gluconolactone $\xrightarrow{\text{Hydrolysis}}$ Gluconic acid
Triolein	Lipase	Triolein $\xrightarrow{\text{Hydrolysis}}$ Glycerol + oleic acid

Integrated ISFET Chip

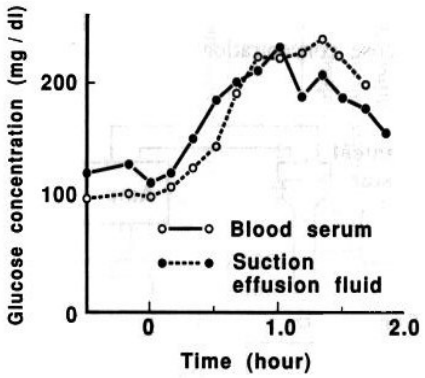


Glucose measurement using ISFET





Suction Cell

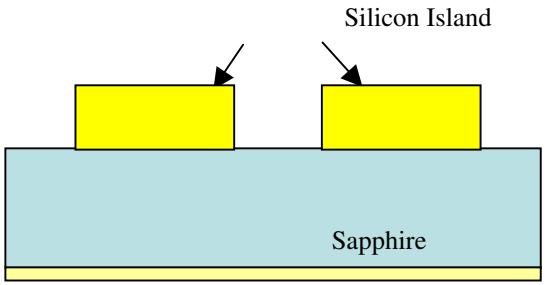


Insulating Methods

	Insulating method	Characteristics
Resin coating	Cover bare silicon region with resin	
Film resist	Cover with patterned film resist	Micropool
Needle type	Anisotropic etching of silicon wafer to obtain a Si needle, which is covered with insulation layers	Needle shape, very small sample can be measured
SOS[a]	ISFET is made in a silicon island on a sapphire wafer	Compatible with normal IC process, chemically stable, complete insulation
p-n Junction	Isolation by *p-n* junction	Compatible with normal Si process

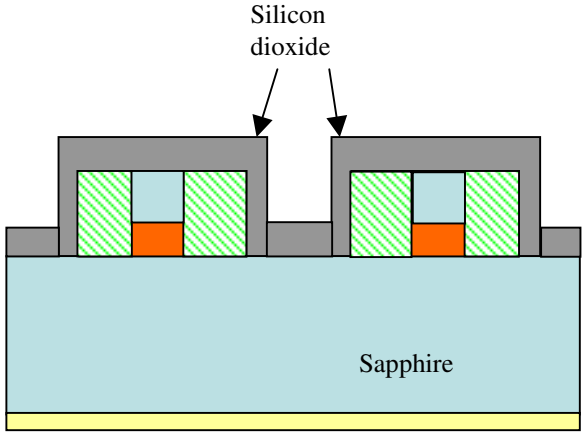
ISFET Fabrication (Silicon on Sapphire)

1 **Silicon Island Formation:**



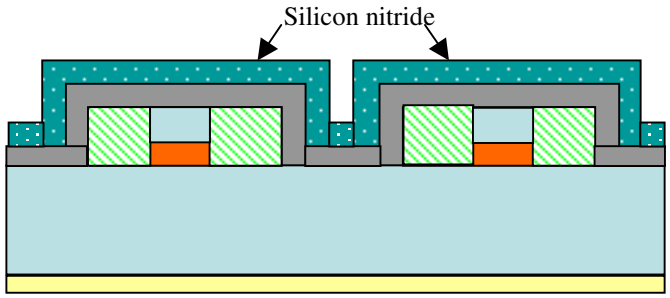
♣ Silicon Islands built over the Sapphire wafer.

2 **FET Fabrication:**



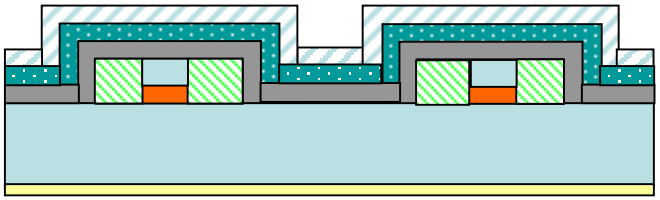
♣ p type and n type regions are formed by ion implantation and SiO2 layer deposited.

3



• Silicon Nitride is deposited over the Silicon dioxide layer by LPCVD.

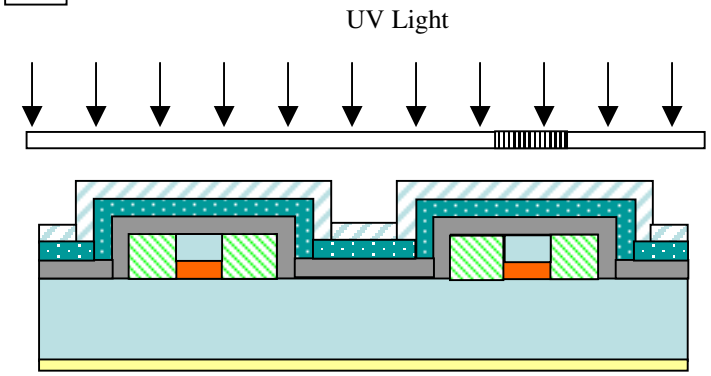
4



•Glucose oxidase, bovine serum albumin and photopolymer solution are dropped on the wafer surface which is spun at 2000rpm.

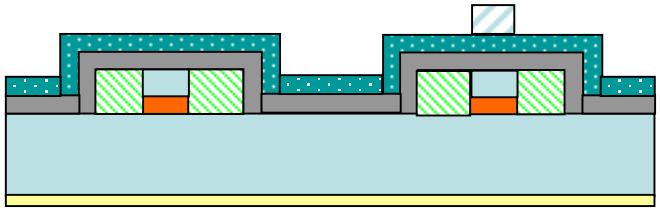
Fabrication of ISFET (Contd…)

5



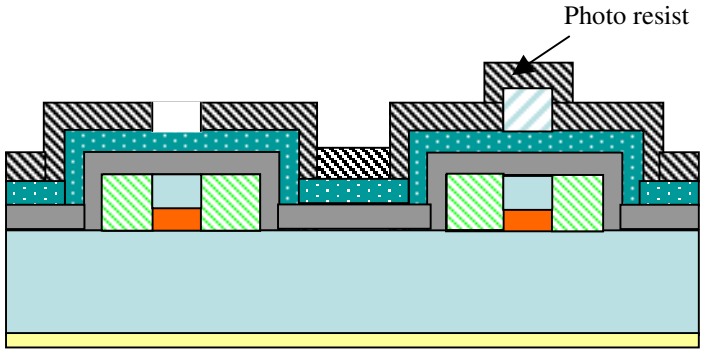
- Partial inactivation of Immobilized Membrane:
- Enzyme around gate is exposed to UV light. Glucose oxide formed on the wafer.

6



- Lift off

7



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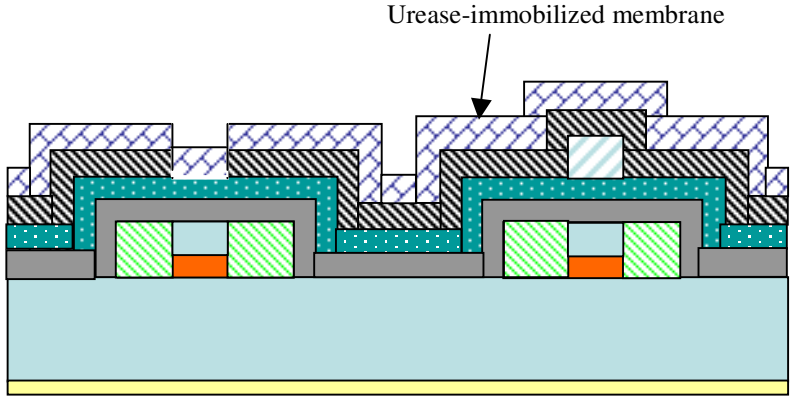
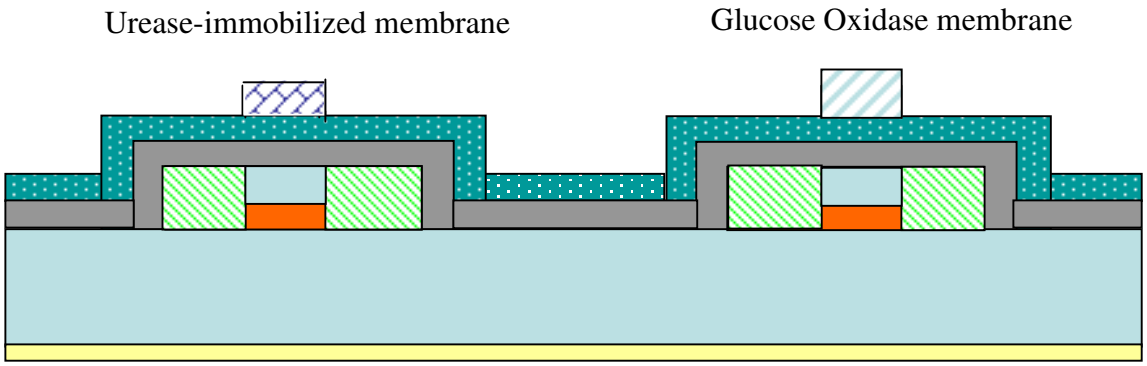
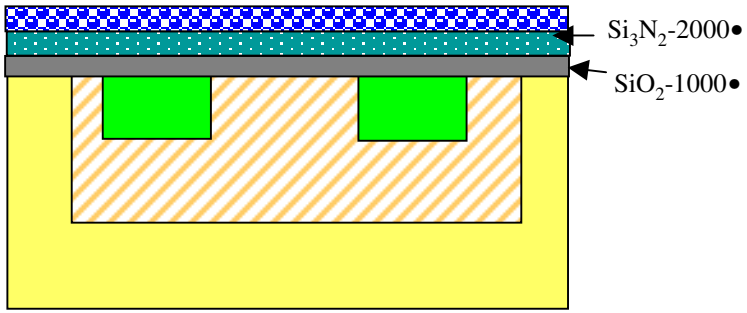


9 **Lift-Off:**

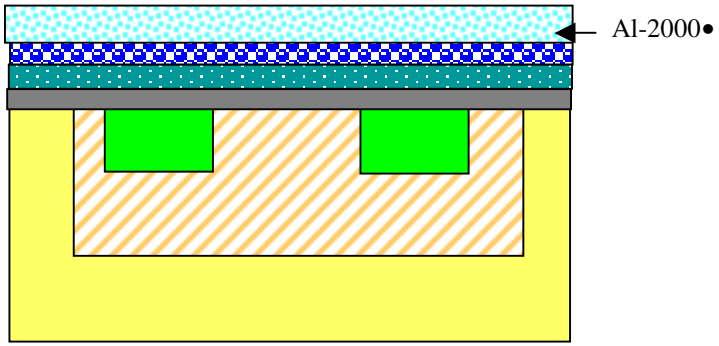


ISFET in Standard CMOS

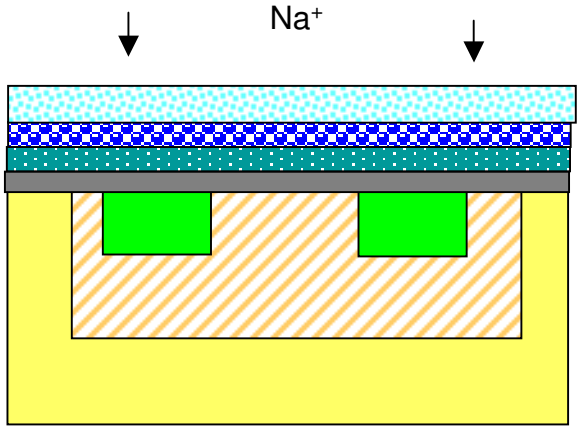
1 Oxidation at 1000^0 C



2 Al Evaporation at 1000^0 C

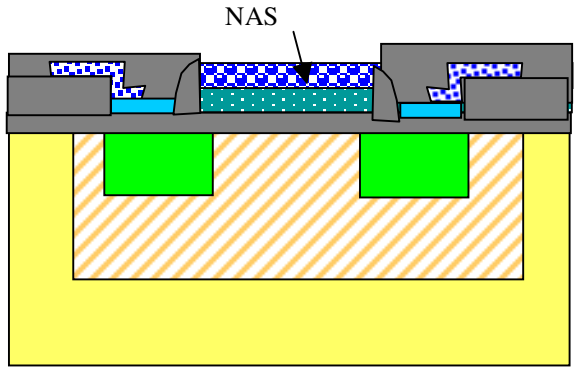


3



Na Ion implantation

4



After Na Ion implantation, Al buffer layer removal, metallization and Oxide formation
NAS- Sodium alumino silicate

IEEE Tran. Electron Devices, Jan 1988, pg 56

ISFET

- MOSFET in which gate metal is replaced by an aqueous solution
- Membrane is hydrated when exposed to aqueous solution
- The potential difference across the interface of membrane and solution is given by Nernst equation,

$$\Phi_{ox} - \Phi_{sol} = Const + \frac{RT}{F} \ln\left(a_{H^+_{sol}} + Ka_{Na^+_{sol}}\right)$$

where

$a_{H^+_{sol}}$ = *Activity of* H^+ *ions in the solution*

$a_{Na^+_{sol}}$ = *Activity of* Na^+ *ions in the solution*

F = *Faraday Constant*

R = *gas Constant*

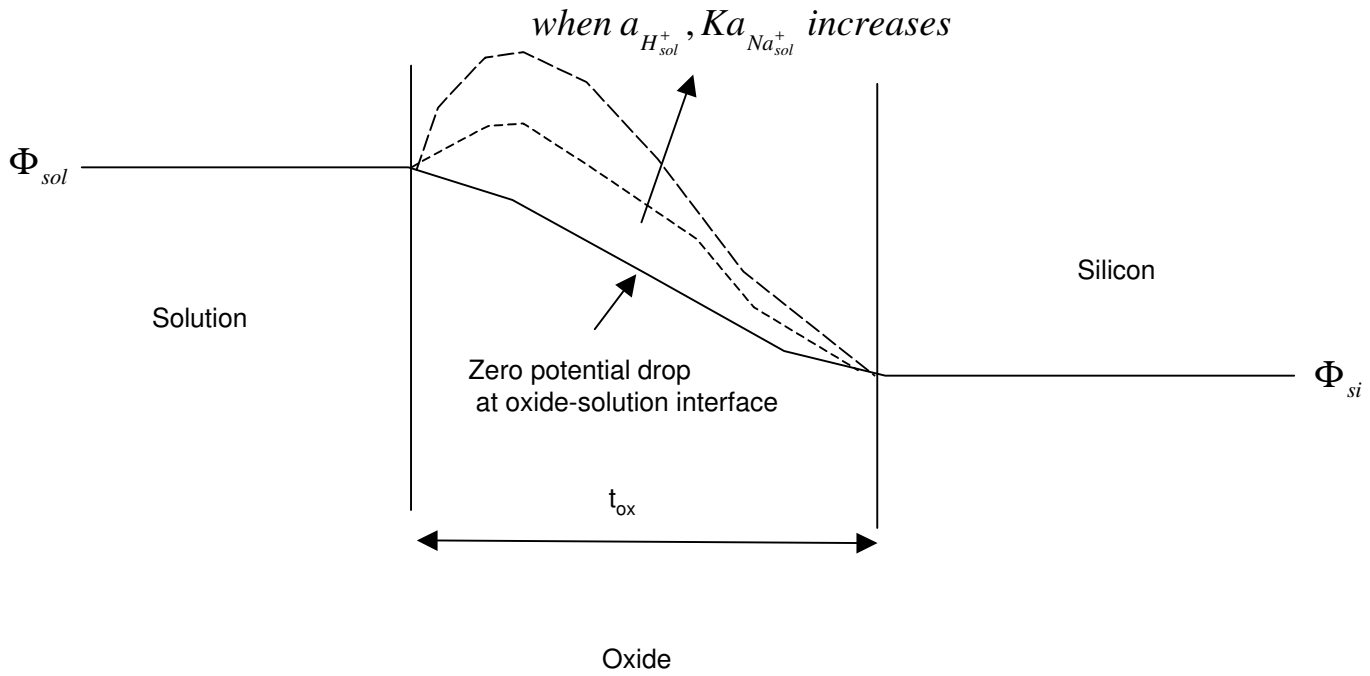
T = *Absolute Temperature*

K = *Ion exchange constant of the membrane*

Drain Current

$$I_{ds} = \beta V_{dd}\left[\left\{Const + \frac{RT}{F}\ln\left(a_{H^+_{sol}} + Ka_{Na^+_{sol}}\right)\right\} - \frac{a}{C_{ox}}[V_b']^{1/2}\right]$$

Potential Distribution of Solution-Oxide-Silicon system



DC Characteristics of ISFET

Drain Current

$$I_{ds} = \beta V_{dd}\left[\left\{Const + \frac{RT}{F}\ln\left(a_{H^+_{sol}} + Ka_{Na^+_{sol}}\right)\right\} - \frac{a}{C_{ox}}[V_b']^{1/2}\right]$$

where

$a_{H^+_{sol}}$ = *Activity of* H^+ *ions in the solution*

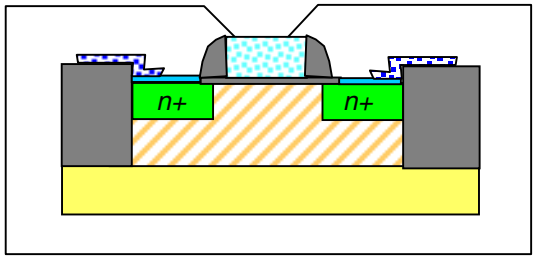
$a_{Na^+_{sol}}$ = *Activity of* Na^+ *ions in the solution*

F = *Faraday Constant*

R = *gas Constant*

T = *Absolute Temperature*

K = *Ion exchange constant of the membrane*


n+
n+